(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 May 2001 (17.05.2001)

PCT

(10) International Publication Number
WO 01/35551 A1

(51) International Patent Classification⁷: H04B 10/00

(21) International Application Number: PCT/KR00/01279

(22) International Filing Date: 8 November 2000 (08.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1999/49564 9 November 1999 (09.11.1999) KR
2000/36574 29 June 2000 (29.06.2000) KR

(71) Applicant: BUDDATEC CO., LTD. [KR/KR]; Rm419, Dong-Seoul Terminal Bld. 546-1, Gui-Dong, Kwangjin-ku, Seoul 143-200 (KR).

(72) Inventor: KIM, Anderson, H.; 641, Buenaventra Court Toms River, NJ 08753 (US).

(74) Agent: KIM, Sun-young; 10th Floor, Korea Coal Center, 80-6, Susong-Dong, Chongro-Ku, Seoul 110-727 (KR).

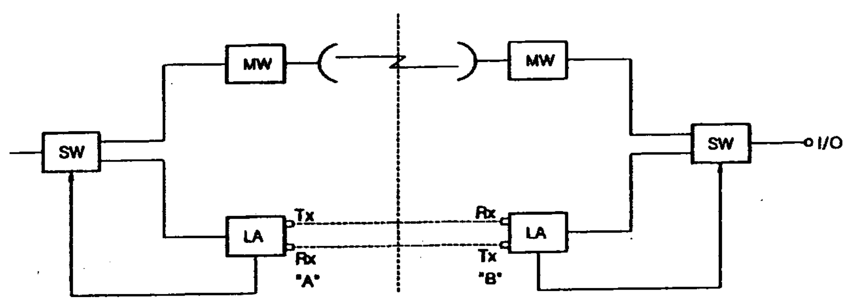
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LASER AND MICROWAVE HYBRID COMMUNICATION METHODS AND SYSTEMS



(57) Abstract: The hybrid communication system of the present invention comprises: a laser communication device; a microwave communication device; and a switching means which, equipped with a received signal strength indicator monitoring the magnitude of received signals at the laser communication device, connects the input/output port for the communication to the input/output port of the microwave communication device for communication by the microwave communication device if the output measured at the said received signal strength indicator is less than a predetermined threshold value. The laser and microwave hybrid communication method of the present invention comprises: (a) a laser communication step; (b) a signal magnitude measuring step in which the magnitude of the received laser signals is measured during the laser communication; (c) a step in which, if the magnitude of the received laser signals measured at the said step (b) is less than a threshold value, the input/output port for communication is connected to the microwave communication device's input/output port in order to enable the communication by the microwave signals; (d) a monitoring step in which the magnitude of the received laser signals is monitored even while the said step (c) is conducted; and (e) a step in which, if the magnitude of the received laser signals measured at the said step (d) has become greater than the threshold value, the input/output port for communication is again connected to the laser communication device's input/output port. With such systems, at normal conditions, communication by laser is conducted. However, when the magnitude of signals received by the laser communication is below the threshold value due to weather conditions such as fogs, the present invention enables communication by microwave, complementing the weakness of the laser communication.

WO 01/35551 A1

LASER AND MICROWAVE HYBRID COMMUNICATION METHODS AND SYSTEMS

TECHNICAL FIELD

The present invention relates to hybrid communication methods and systems whereby laser communication and microwave communication may be adopted. In particular, the present invention relates to the laser and microwave hybrid communication method and system, which makes it possible to primarily conduct the laser communication and occasionally conduct the microwave communication, depending on the weather conditions.

BACKGROUND ART

As wireless communication methods, there are the microwave communication and the laser communication. The microwave communication method is a wireless communication method using the microwaves including the radio frequency (RF). The laser communication is another wireless communication method which primarily uses semiconductor laser light. Each of these methods has its strength and weakness.

The laser communication does not entail radio interference because it uses ultra high frequency semiconductor laser light which is in the range of tera-hertzs. Also, there is no administrative regulation on the frequency band for the laser communication, and the communication quality is excellent. However, the laser communication has a weakness that it is susceptible to weather conditions such as fogs. For example, when there are severe fogs, the attenuation in the laser communication may become so great that the communication stoppage may occur. This presents a serious problem in constructing medium to long distance wireless communication networks using the laser

communication.

In contrast, the microwave communication is not so easily affected by fogs. However, there often are frequency interferences in the microwave communication, lowering the communication quality.

DISCLOSURE OF THE INVENTION

A purpose of the present invention is to provide communication methods and systems which complement the laser communication which is susceptible to fogs.

Another purpose of the present invention is to provide laser and microwave hybrid communication methods and systems which, in order to complement the weakness of the laser communication, occasionally adopt the microwave communication when the quality of the laser communication is deteriorated due to fogs.

In order to achieve the aforementioned purposes, the laser and microwave hybrid communication method and system according to the present invention, equipped with both the laser communication device and the microwave communication device, ordinarily conducts communication using the laser communication method but, when the magnitude of the received laser signal is less than a threshold value, conducts the microwave communication through the switching means enabling such conversion.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a structure diagram of the present invention's system.

Fig. 2 is a diagram to illustrate the general feature of the laser communication method.

Fig. 3 is a structure diagram of the switching means of the present invention's system.

Fig. 4 is a structure diagram of the light receiver of the general laser communication device.

Fig. 5 is a timing diagram illustrating the switching actions to the microwave communication device in the system according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Provided in the following are the detailed explanations of the laser and microwave hybrid communication method and system of the present invention with references to the drawings.

Fig. 1 is a structure diagram of the present invention's system.

Fig. 1 depicts communication between sides "A" and "B," both of which use the laser and microwave hybrid communication system implemented according to the present invention.

The laser and microwave hybrid communication system of the present invention, illustrated in Fig. 1, comprises a laser communication device (LA), a microwave communication device (MW) and a switching means (SW) which is capable of selecting one of these two communication methods.

The laser communication device (LA) modulates communication signals into laser signals and transmits such signals to the other side through the light transmitter (Tx). Such laser communication device (LA) receives laser signals transmitted from the other side at the light receiver (Rx) and demodulates such signals. The microwave communication device (MW) modulates communication signals into microwaves to transmit them to the other side and demodulates the received microwaves to regenerate the communication signals.

The switching means (SW) selects either the laser communication device (LA)

or the microwave communication device (MW) depending on fog conditions. Ordinarily, the laser communication device (LA) is used for communication in this system but when the magnitude of signals received through the laser communication device is below a threshold value, the microwave communication device (MW) is selected for communication using the microwaves. Selection of one of the communication devices by the switching means (SW) is implemented in the following manner. If the laser communication device (LA) is selected by the switching means (SW), the input and output port of the laser communication device is connected to the input and output port of the overall system. In the same manner, if the microwave communication device (MW) is selected by the switching means (SW), the input and output port of the microwave communication device is connected to the input and output port of the overall system.

On the other hand, even when the laser communication device (LA) is not selected for communication by the switching means (SW), signals received at the laser communication device (LA) are inputted to the switching means (SW) for measurement of such signals' magnitude by the received signal strength indicator (to be described in the following) within the switching means (SW). In other words, the switching means (SW) of the present invention's system monitors the magnitude of signals received by the laser communication method.

If fogs cause the magnitude of received laser signals, inputted to the switching means (SW), to be lessened below a predertermined threshold value, the switching means (SW) connects the input and output port of the system to the microwave communication device (MW)'s input and output port in order to conduct communication by microwaves. If the fogs disappear resulting in the magnitude of the received laser signals' increase over the threshold value, the switching means (SW) connects the input and output port of the system to the laser communication device (LA)'s input and output port for laser

communication. As the quality of laser communication is generally superior, it is desirable to use the laser communication in the ordinary times and to use the microwave communication only when the reception of the laser signals is deteriorated because of fogs. If fogs disappear and the laser communication's quality is recovered, it is thus desirable to convert back to the laser communication.

Fig. 2 is a diagram to illustrate the general feature of the laser communication method.

Laser signals are severely attenuated when they pass through the atmosphere containing fogs. Due to such attenuation, effective coverage of laser communication devices is limited and, in severe cases, communication stoppage may occur.

As illustrated in Fig. 2, if the laser communication method is used for communication between spots a and b, laser transmitted from the light transmitter (Tx) into the air loses its energy during propagation due to particles in the air such as dust and fogs. Also, the energy attenuation of laser transmitted into the air is dependent on the diverging angle (α) and the size of lens at the receiving end. The attenuation by particles such as dust and fogs is called the "weather condition attenuation," and the attenuation by the other elements is called the "reception area attenuation." In order that the laser communication may be feasible, the sum of the weather condition attenuation and the reception area attenuation must not be less than –90dB.

The reception area attenuation is determined by the following equation, depending on square measure (or diameter) of laser beam at the reception end and square measure (or diameter) of the lens at the light receiver if the distance between the transmission end and the reception end is 1km.

(Laser output from the transmission end) x [square measure of the lens at the

light receiver(or diameter) / square measure of laser beam (or diameter)]

For example, if the diverging angle (α) is 1mRd when the distance between the transmission end (a) and the reception end (b) is 1km, the diameter (S) of laser beam transmitted from the transmission end (a) at the reception end (b), which is 1km apart from (a), is 1m. With S being 1m, if the laser output is 20mW and if diameter of the lens at the light receiver is 100mm, then the "reception area attenuation" calculated according to the aforementioned equation would be –27dB.

The "weather condition attenuation" due to thick fogs would be approximately –50dB/km if the visibility range is 270m, and approximately –70dB/km if the visibility range is 200m. Thus, in fogs with the visibility range from 200m to 270m, the sum of the "reception area attenuation" and the "weather condition attenuation" may be approximately from –77dB to –97dB. As the current minimum sensitivity of the laser beam signal detector is –90dB, the sum of the "weather condition attenuation" and the "reception area attenuation" must not be less than –90dB for laser communication.

In downtown areas, there are only several days in a year when fogs are thick enough to hinder the laser communication. Thus, the laser and microwave hybrid communication method and system according to the present invention adopts the laser communication for ordinary times and uses the microwave communication only when the laser communication is impaired by fogs.

Provided in the following, with the references to Fig. 3, Fig. 4 and Fig. 5, are detailed explanations of the switching actions from the laser communication to microwave communication, and vice versa, of the present invention's laser and microwave hybrid communication method and system.

Fig. 3 is a structure diagram of the switching means of the present invention's

system.

The switching means (SW) comprises a received signal strength indicator (RSSI) which receives the electric received signal, which has been received and modulated at the light receiver (Rx) of the laser communication device (LA), and generates a voltage signal which is proportional to the strength of such received signal; a comparator (Comp.) which compares the magnitude of the voltage signal outputted from the said received signal strength indicator (RSSI) with the predetermined threshold value and outputs a voltage signal (LOS, Los of signal) with a logic level depending on the result of such comparison; a control unit (CC) which generates a switching control signal (SC) based upon the logic level of the voltage signal outputted from the comparator (Comp.); and a switching unit (SB) which connects the input/output port of the communication system either to the laser communication device (LA)'s input/output port or to the microwave communication device (MW)'s input/output port based on the switching control signal (SC) which is inputted from the control unit (CC).

The received signal strength indicator (RSSI) generates a voltage signal proportional to the magnitude of the signals received at the light receiver (Rx) of the laser communication device (LA). As shown in the structure diagram of the light receiver (Rx) of a general laser communication device in Fig. 4, the laser received at the lens at the light receiver (Rx) is converted into a electric signal by the APD module and limiter circuits. Such received signal is inputted to the received signal strength indicator (RSSI) of the switching means (SW).

In the received signal strength indicator (RSSI), a voltage signal proportional to the received signal strength is generated and such voltage signal is inputted to the comparator (Comp.).

The comparator (Comp.) compares the strength of the electric received signals,

inputted from the light receiver (Rx), with the threshold value (predetermined), and generates a voltage signal (LOS) with a logic level value based upon the result of such comparison. Such voltage signal is inputted to the control unit (Cc).

The control unit (CC) generates a switching control signal (SC) according to the voltage signal (LOS) outputted from the comparator (Comp.). The switching control signal (SC) enables the input/output port of the overall communication system to be connected to the laser communication device (LA)'s input/output port when the received signal strength is greater than the threshold value, or to the microwave communication device (MW)'s input/output port when the received signal strength is less than the threshold value.

The switching unit (SB) connects the input/output port for communication either to the laser communication device (LA)'s input/output port or to the microwave communication device (MW)'s input/output port based upon the switching control signal (SC) transmitted from the said control unit (CC).

The operation of the present invention's laser and microwave hybrid communication system, having the above-described structure, is explained in the following.

In the initial state, the input/output port for communication is connected to the laser communication device (LA)'s input/output port. Thus, communication using the laser communication device (LA) is conducted. If fogs are formed and the received signals' strength at the laser communication device (LA) gradually decreases due to such fogs until the signal strength measured at the received signal strength indicator (RSSI) becomes less than the threshold value, the level of the voltage signal (LOS) outputted from the comparator (Comp.) is changed. Then, the switching control signal (SC) to be outputted from the control unit (CC) is determined accordingly. Finally, in the switching

unit (SB), the switching of the input/output port for communication from the laser communication device (LA) to the microwave communication device (MW) is conducted, enabling communication to be conducted by the microwave communication device (MW).

Even during the communication using the microwave communication device (MW), the strength of laser communication signals received at the light receiver (Rx) of the laser communication device (LA) is monitored at the received signal strength indicator (RSSI) of the switching means (SW). During such monitoring, if the strength of the received laser signals becomes greater than the threshold value, the level of the voltage signal (LOS) outputted from the comparator (Comp.) is generated and thus the switching control signal (SC) from the control unit (CC) is determined accordingly, making the switching unit (SB) conduct switching of the input/output port for communication from the microwave communication device (MW) to the laser communication device (LA). Therefore, communication by the laser communication device (LA) is enabled.

Fig. 5 is a timing diagram illustrating the switching actions to the microwave communication device in the system according to the present invention.

LOS in Fig. 5 is a voltage signal outputted from the comparator (Comp.) of the switching means (SW) as a result of the comparison of the voltage value, indicating the signal strength outputted from the received signal strength indicator (RSSI), with the standard voltage value. Fig. 5 illustrates an example wherein LOS is converted to "High Level" if the received laser signal's strength is less than the threshold value. In Fig. 5, "tp" is the time interval between the LOS' conversion to "High Level" and the completion of switching to the microwave communication device (MW). In other words, not until time "tp" has passed after the conversion of LOS to the "High Level," is switching to the microwave communication device (MW) complete. The switching

action is conducted with such time interval in order to prevent the microwave communication device (MW) from being enabled in an occasion where the laser signal strength is momentarily reduced and recovered immediately thereafter. The value of "tp" may be specified by a user in the range of 0.05ms to 200ms.

The present invention's laser and microwave hybrid communication method and system uses both the laser communication device and the microwave communication device. With such system, at normal conditions, communication by laser is conducted. However, when the magnitude of signals received by the laser communication is below the threshold value due to weather conditions such as fogs, the present invention enables communication by microwave, complementing the weakness of the laser communication.

WHAT IS CLAIMED IS

1. A laser and microwave hybrid communication system, comprising:

a laser communication device which modulates electric signals into laser signals and transmits such signals, and which receives laser signals transmitted from the other side and demodulates such signals into electric signals;

a microwave communication device which modulates electric signals into microwave signals and transmits such signals, and which receives microwave signals transmitted from the other side and demodulates such signals into electric signals; and

a switching means which, equipped with a received signal strength indicator monitoring the magnitude of received signals at the laser communication device, connects the input/output port for the communication to the input/output port of the microwave communication device for communication by the microwave communication device if the output value measured at the said received signal strength indicator is less than a predertermined threshold value.

2. The laser and microwave hybrid communication system according to claim 1, wherein the said switching means comprises:

a received signal strength indicator which receives the electric received signals, which have been received and demodulated at the light receiver of the laser communication device, and generates a voltage signal which is proportional to the strength of such received signal;

a comparator which compares the magnitude of the voltage signal outputted from the said received signal strength indicator with the predetermined threshold value, and outputs a voltage signal with a logic level depending on the result of such comparison;

a control unit which generates a switching control signal based upon the logic level of the voltage signal(LOS) outputted from the comparator; and

a switching unit which connects the input/output port of the communication system either to the laser communication device's input/output port or to the microwave communication device's input/output port based on the switching control signal which is inputted from the control unit.

3. The laser and microwave hybrid communication system according to claim 2, wherein the said switching unit at the initial state connects the input/output port for communication to the input/output port of the laser communication device.

4. The laser and microwave hybrid communication method, comprising:

(a) a laser communication step in which electric signals are modulated into laser signals and transmitted, and the laser signals transmitted from the other side are received and demodulated into electric signals;

(b) a signal magnitude measuring step in which the magnitude of the received laser signals is measured during the laser communication;

(c) a step in which, if the magnitude of the received laser signals, measured at the said step (b) is less than the threshold value, the input/output port for communication is connected to the microwave communication device's input/output port in order to enable the communication through the microwave signals;

(d) a monitoring step in which the magnitude of the received laser signals is monitored even while the said step (c) is conducted; and

(e) a step in which, if the magnitude of the received laser signals, measured at the said step (d), becomes greater than the threshold value, the input/output port for

communication is again connected to the laser communication device's input/output port.

5. The laser and microwave hybrid communication method according to claim 4, wherein the switching action connecting the input/output port for communication to the microwave communication device's input/output port in the said step (c) is taken when a time interval of "tp" passes after the strength of the received laser signal becomes less than the threshold value.

Fig. 1

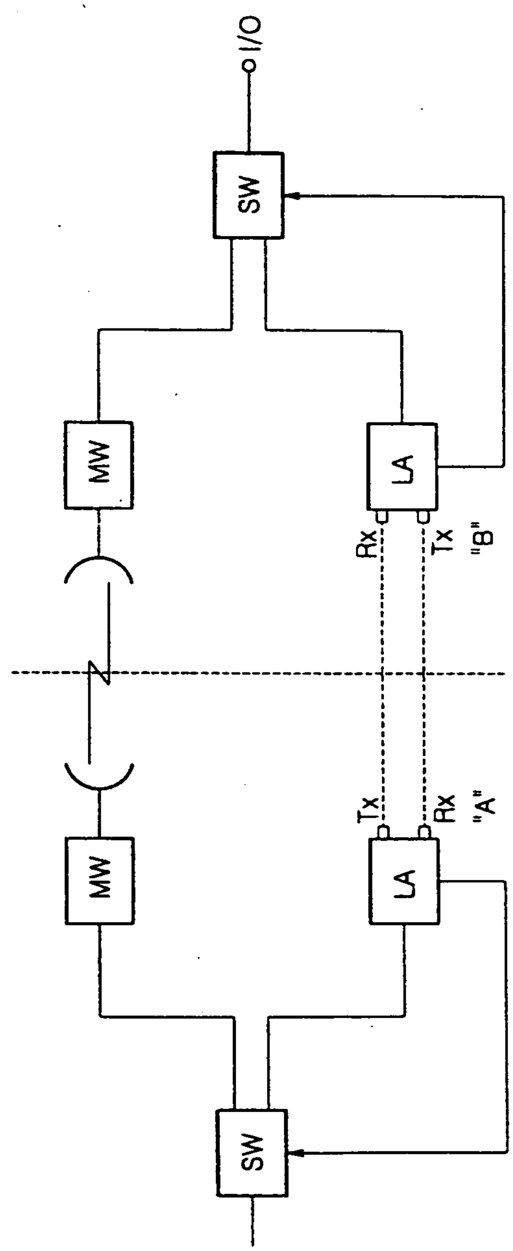


Fig. 2

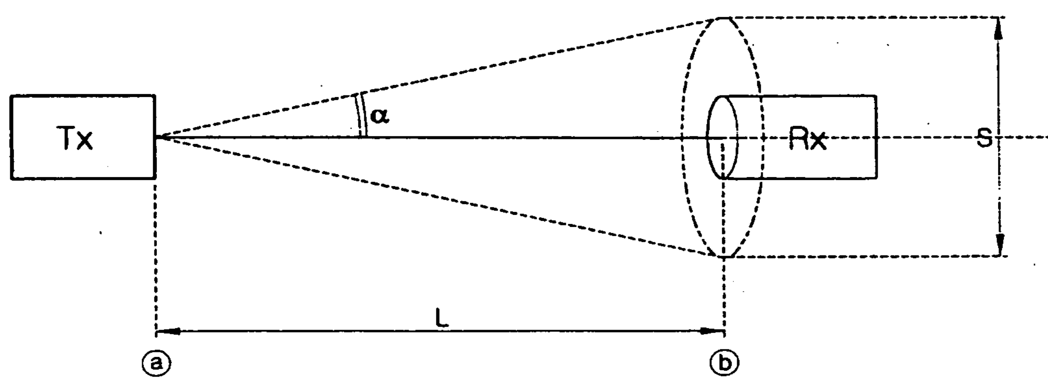


Fig. 3

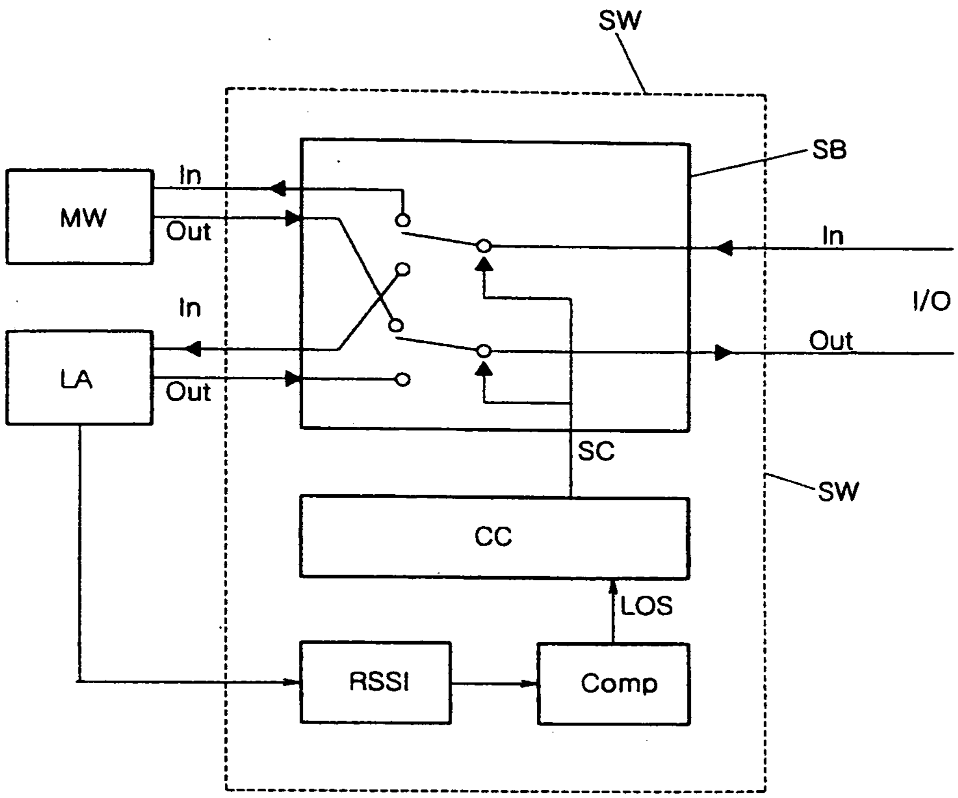

SW
SB
MW
In
Out
In
LA
Out
In
I/O
Out
SC
SW
CC
LOS
RSSI
Comp

Fig. 4

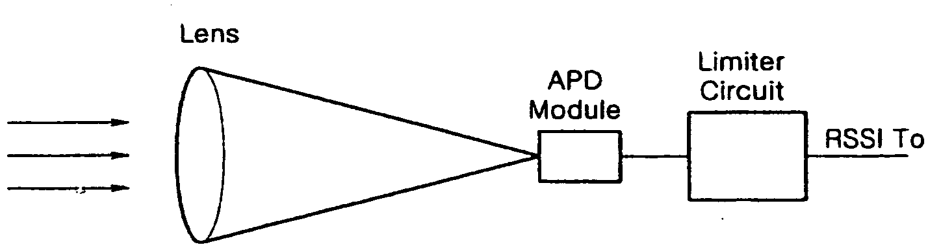
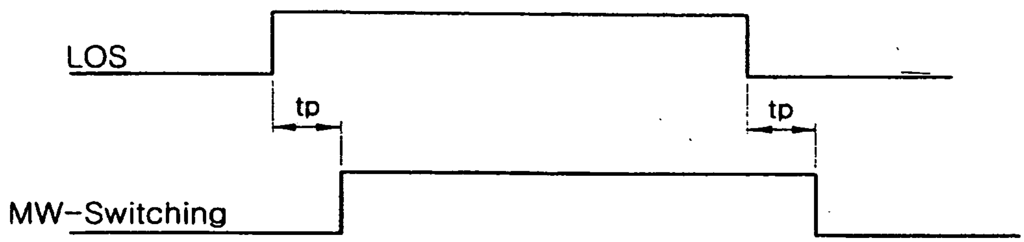

Lens
APD
Module
Limiter
Circuit
RSSI To

Fig. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/01279

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04B 10/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 H04B 9/00, 10/00, 10/22, H04J 3/26

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5479595 A (Telefonaktiebolaget LM Ericsson) 26 December 1995 (26.12.95) See the abstract	1-5
A	US 5479408 A (Craig A. Will) 26 December 1995 (26.12.95) See the abstract	1-5
A	US 4928317 A (Societe Anonyme dite: Alcatel Espace, Courbeyoie, France) 22 May 1990 (22. 05. 90) See the abstract	1-5
A	US 5307194 A (Grumman Aerospace Corp.) 26 April 1994 (26. 04. 94) See the abstract	1-5
A	US 5493436 A (Kokusai Denshin Denwa Company, Ltd.) 20 February 1996 (20. 02. 96) See the abstract	1-5

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevence

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 FEBRUARY 2001 (20.02.2001)	21 FEBRUARY 2001 (21.02.2001)

Name and mailing address of the ISA/KR

Korean Industrial Property Office
Government Complex-Taejon, Dunsan-dong, So-ku, Taejon
Metropolitan City 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

SONG, In Kwan

Telephone No. 82-42-481-5708

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/01279

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5880868 A (Intermec IP Corp.) 09 March 1999 (09. 03. 99) See the abstract	1-5
A	US 4873681 A (Bell Communications Research, Inc.) 10 October 1989 (10. 10. 89) See the abstract	1-5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR00/01279

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5479595 A	26.12.95	None	
US 5479408 A	26.12.95	None	
US 4928317 A	22. 05. 90	None	
US 5307194 A	26. 04. 94	None	
US 5493436 A	20. 02. 96	None	
US 5880868 A	09. 03. 99	None	
US 4873681 A	10. 10. 89	None	